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A note on an instrument for the continuous recording of soil temperatures

by
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Introduction

The need arose at Cambridge to record soil temperatures at a number of depths below various crop surfaces. Previously such records have been obtained by using mercury in steel thermographs (see e.g. Hutchings 1952), platinum resistance thermometers (see e.g. Johnson and Davies 1927) and single thermojunctions working in conjunction with photographic galvanometer recorders (see e.g. de Villiers 1951). In siting these instruments, considerable quantities of soil have to be removed and replaced and any vegetation cover is at least severely damaged. The instrument to be described depends upon the thermo-electric principle and is a development of that used by Pasquill (1949) and others in heat balance observations for which the indications of a sensitive eye reading galvanometer at relatively infrequent intervals were sufficient. It is simple to construct, requires a minimum of attention when in operation, does not disturb the soil cover to any great extent on siting, and provides an immediately visible record at a convenient distance from the site. No power supplies other than one six volt accumulator are required.

General Construction

The thermometer as constructed enables temperatures at five depths namely, 1, 5, 10, 20 and 40 cm. to be recorded to 0.1°F over a range of approximately 60°F when working with the recording galvanometer to be described. A view of the thermometer, together with certain constructional details, is shown in Fig. 1. It consists of a Tufnol tube $1\frac{1}{2}$ in. outside diameter and $\frac{3}{4}$ in. inside diameter which is closed at one end by a brass spike and at the other by a brass cap. Copper plugs which form the thermometer bulbs are inserted through the wall of the Tufnol tube at appropriate intervals along its length and, at each depth, three bulbs are inserted 120° apart around the tube. Thus three complete sets of bulbs are provided, S_1, S_2 and S_3 of Fig. 2 which shows a schematic wiring diagram. Each set has a reference junction (R_1, R_2 and R_3, Fig.2) which is normally kept in melting ice contained in a vacuum flask. The thermojunctions are made from enamelled 28 s.w.g. constantan and 32 s.w.g. copper wire. Each bulb has a hole drilled through its centre into which a pair of the wires is soldered, each thermojunction pair being made up of the same lengths of wire and covered with P.V.C. sleeving. The bulbs are tight push fits in the Tufnol and, to give added strength, are stuck in position with Araldite D. After insertion the bulbs are filed to be flush with the wall of the tube and the instrument is covered with a coating of Araldite to insulate the copper bulbs and render the whole watertight. The thermocouple leads are brought up the centre of the tube and leave near its upper end by way of three short brass side tubes which are screwed into the Tufnol wall, the wires from one set of bulbs leaving by each tube.

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They are terminated in junction boxes where they are joined by those from the reference junctions. Between the thermometer and the junction boxes the leads are protected by P.V.C. sleeving which fits tightly over the brass side tubes at one end and over the junction boxes at the other. At these boxes the constantan leads of each of the three sets, together with that from the appropriate reference junction, are soldered together. Any excess lengths of lead are contained in these boxes. A six core cable with single 22 s.w.g. copper conductors leaves each of the three junction boxes and leads to the recorder. As constructed at Cambridge, the cables are 100 yd. long.

An Elliot six circuit, six colour recording galvanometer having a coil resistance of 35 ohms and a full scale deflection for 40 microamps is used. This recorder, as supplied by the makers, has a double pole six position rotary switch for circuit selection which is operated by an electromagnet which also actuates the colour changing mechanism. The switching interval is 2 min. and is regulated by a clock attached to the instrument. A 6 volt D.C. supply is required.

The eighteen copper leads from the thermometer are brought to a board near the recorder on which are mounted six P.O. type 3000 relays (100 ohm, 6 volt operating), the M's of Fig. 2. Each has two platinum contact pairs which are made on energising the relay. In Fig. 2 only five relays are shown, the sixth being used to provide a zero position on the galvanometer chart. They are energised in the required sequence by applying current through one side of the rotary switch in the recorder, the recorder wiring being modified for this purpose. The other side of the switch, I of Fig. 2, is used as indicated in that figure. The back e.m.f. produced on switching the relays is suppressed by the use of a condenser and resistance circuit across each relay coil and arcing at the rotary switch is avoided. Thus at each depth at which a temperature record is required, we have in effect a thermopile having three "hot" and three "cold" junctions. The output from a single thermocouple pair is insufficient to provide the necessary current to give a reasonably open scale of temperature on the recorder chart, unless the galvanometer employed has a much higher current sensitivity or D.C. amplifiers are available. The use of a more sensitive galvanometer would entail photographic recording which is never convenient on a field site and the use of D.C. amplifiers leads to well known complications.

The apparatus provides a record of the temperature at each of the five depths once in 12 min. and there is no possibility of the recording mechanism becoming out of step with the relays. Soil temperatures below freezing point can be recorded by moving the zero position of the galvanometer, which represents 32°F, and when such conditions are anticipated the galvanometer zero is set some way up the chart.

Calibration

The thermometer and its associated recorder are calibrated as a single unit. The calibration is conducted in the normal way by the use of stirred water baths. After reasonable care in construction the calibration factor is found to be the same for the circuits at all depths. However, calibration shows an increase in deflection per degree with increase in temperature, the increase amounting to a change of 4 per cent. over the temperature range 30°F to 90°F. The overall resistance of a circuit for one depth, including the galvanometer and 100 yd. of cable, is approximately 95 ohms, and one scale division of the chart represents approximately 1.4°F. No change in the calibration factor could be detected as a result of heating by the relay operating coils, the relays being mounted so that any heat generated would have the minimum effect on the contacts.

Field Use

The thermometer is driven into the soil and the cables are led away to a portable hut which houses the recorder and accumulator. The only attention

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required is a replenishment of the ice flask every second day in average summer conditions (lat. 52°N). One 6 volt 65 amp. hr. accumulator will operate the apparatus for one week on a single charge. Three sets of this apparatus have been exposed at Cambridge for eight months and no faults have developed in the thermometers; such loss of record that has occurred has been the result of minor mechanical faults in the recorders. In future it would be more convenient to use one cable with sufficient conductors together with one junction box in place of the three of each at present employed.

Fig. 3 shows a tracing of the record produced by the instrument on 10th May, 1954. In the original, each trace is in a distinctive colour and is much easier to identify than the black and white tracing indicates.

References

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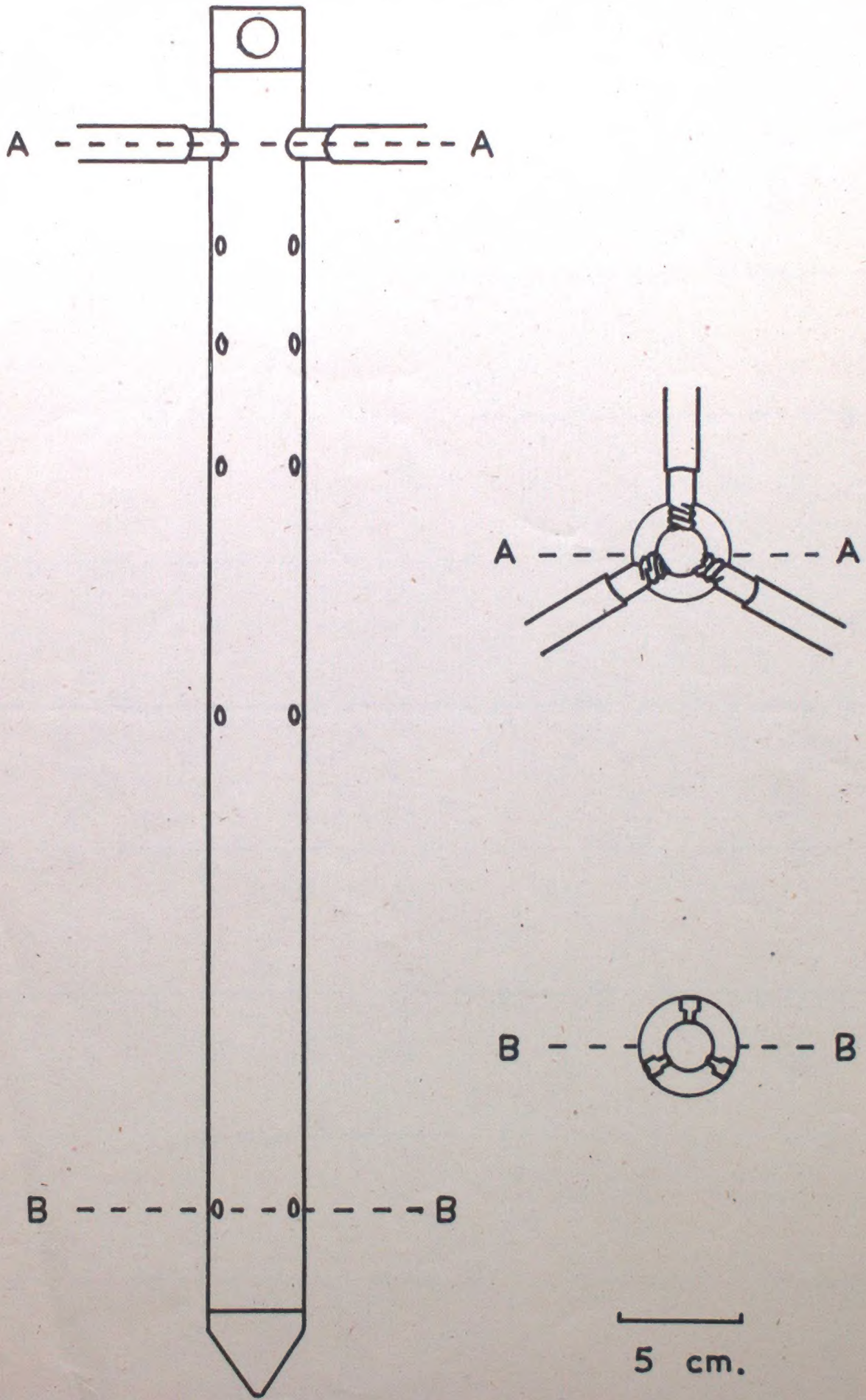


fig 1. General constructional arrangement of Thermometer.

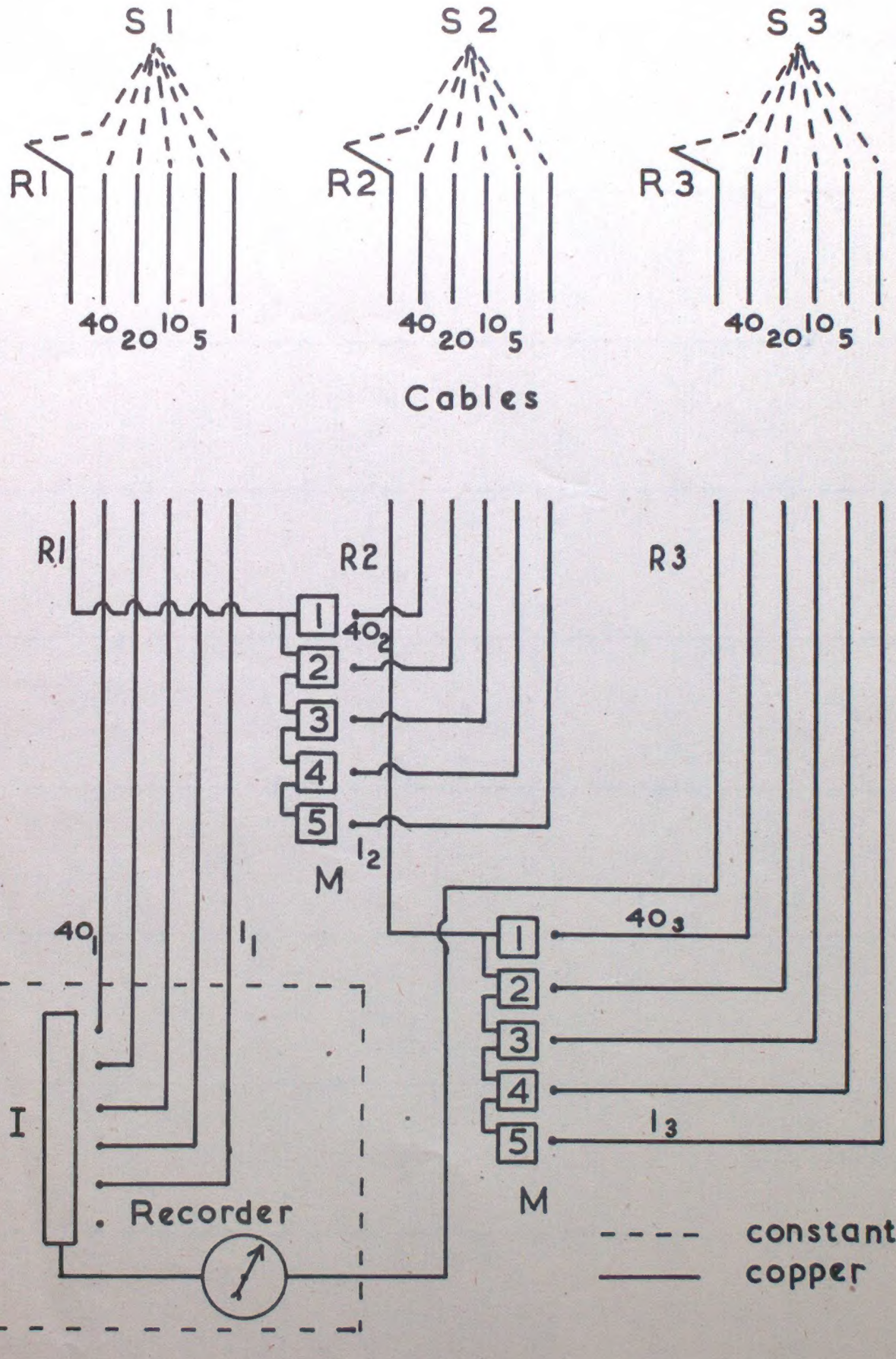
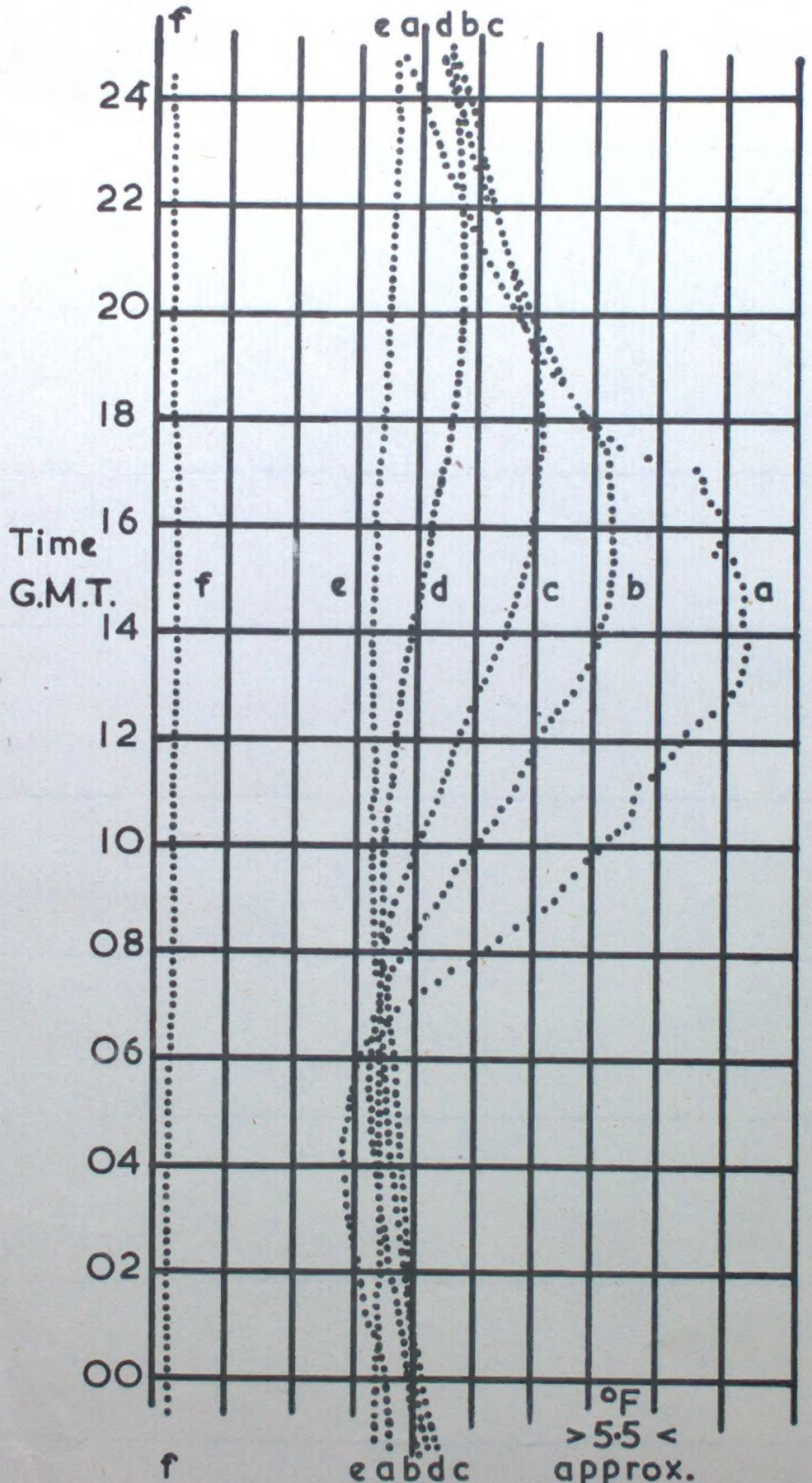


fig 2. Schematic wiring diagram of Thermometer and recording circuits.

fig 3. Tracing of temperature record under bare soil on May 10th., 1954.



Trace a 1 cm. depth. Trace d 20 cm. depth.
" b 5 " " " e 40 " "
" c 10 " " " f zero line (32°F)